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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF RESEARCH AND DEVELOPMENT
RISK REDUCTION ENGINEERING LABORATORY
CINCINNATI, OHIO 45268

DATE: October 9, 1992

SUBJECT: Skinner Landfill Alternative Treatment Technology Evaluations

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The Technical Support Branch of the Risk Reduction Engineering Laboratory received your request letter dated August 12, 1992, for technical assistance for the evaluation of alternative treatment technologies for remediation of the lagoon area at the Skinner Landfill Superfund Site in West Chester, Ohio. It is our understanding that you wish to determine whether any technologies besides incineration could be effective in remediating the lagoon area at this site. (For the purposes of this memorandum, we use the term "alternative treatment technologies" to refer to treatment alternatives to conventional incineration).

A number of treatment technology experts within the Risk Reduction Engineering Laboratory reviewed the information you supplied in the Phase II Remedial Investigation and the Feasibility Study. Evaluations of the following technologies by RREL are based on the data available at this time and are provided for your consideration:

In-situ Treatment Technologies

- in-situ vitrification
- in-situ bioremediation
- soil vapor extraction

Ex-Situ Treatment Technologies

- o plasma torch (plasma arc)
- o stabilization/solidification
- o chemical treatment
- o thermal desorption
- o soil washing
- o solvent extraction
- o ex-situ bioremediation

These technologies were evaluated by RREL, after discussions with you, for one of two reasons. We understood that requests were made by interested individuals to the Region for evaluations of solidification/stabilization, in-situ vitrification and the plasma arc. Other technologies were selected by RREL for evaluation based upon this laboratory's knowledge of developed and demonstrated soil and waste treatment technologies and their potential applicabilities to the contaminants present at the site. We focused on technologies applicable to organic contaminants, although several of the technologies (e.g. soil washing) can also treat metals. We provide a brief description of each technology and then discuss its applicability to the Skinner Landfill lagoon area waste.

IN-SITU-TREATMENT TECHNOLOGIES

In-Situ Vitrification

This technology is intended to treat buried waste in place or "in-situ", without the need for excavation. A high-amperage electrical current is passed between two large vertical electrodes. The electrical resistance heat thus generated will melt, fuse, destroy, and "vitrify" any soil, rock, and organic or metallic pollution in the resulting bowl-shaped melt area. Early developments began with laboratory or pilot-sized melts in drum-sized containers, and expanded-scale testing has been done at a few larger-scale, simulated, multiple-drum waste burial plots.

Conceptually, in-situ vitrification would remediate the expanse of a Superfund site by sequentially melting the required number of individual 30 or 40-foot diameter by 15 to 30-foot deep melted-bowl treatment areas, one by one, somewhat overlapping the melts until the entire site is covered. The melts would encompass and destroy or volatilize any buried toxic waste within reach of the electrodes. When the melts completely cool and solidify, the resulting vitrified material would be free of leachable organics and toxic metals. Gases or vapors escaping upwards from the melting area would be captured and treated by a moveable 55-foot diameter tent-like structure over the active melting sites. The tent is exhausted through an off-gas pollution treatment and control system, driven by an induced-draft fan and having a final discharge stack.

In-Situ Vitrification is a process whose primary developer, the Geosafe Corporation, has temporarily stopped their marketing activities. During a field scale test, the molten lava-like material bubbled violently and caused a fire, partially burning the off-gas collection tent which in this case was constructed of fire-proof cloth. The explosion occurred in a dense drum-to-drum contact situation, where there were high amounts of steel or other metals which could carry electrical current. Higher moisture content wastes are also a problem: the process may never be applicable where groundwater tables are in the proximity of the waste to be treated.

Other concerns that have been expressed are whether some of the toxic organic or metal vapors may migrate, escape, and simply re-locate themselves laterally or downward from the melt zones, or that melt depths much over about 15 feet deep may not be feasible. Because of the uncertainties associated with the technology, and conditions at the landfill including many drums, it is not recommended for the Skinner Landfill site.

<u>In-Situ Bioremediation</u>

In-situ bioremediation of soils involves destruction of organic chemical contaminants without disturbing the soil. This is accomplished by providing nutrients and oxygen (aerobic bioremediation) or other electron acceptors (anaerobic bioremediation) to microorganisms already present in the contaminated soil. Presumably, these microorganisms are acclimated to the chemical contaminants, and at least some will be capable of metabolizing the chemicals as a source of energy. Complete metabolism of the chemicals results in degradation to carbon dioxide and water. This technology provides the advantage of low cost and avoids contaminant dispersal that can result from excavation.

At the Skinner Landfill waste lagoon, stratigraphy data reveal predominantly clay and silt soils with occasional pockets of more permeable sand and gravel. Permeable areas such as sand and gravel may be amenable to in-situ bioremediation by nutrient addition and/or bioventing, in which oxygen is added to the soil by forced air. However, the non-permeable clay and silt areas of the waste lagoon are not candidates for in-situ bioremediation.

Table 3.8 of the RI report shows high oxygen concentration in waste lagoon soil. This indicates that little or no microbial activity is present in this soil. Low soil oxygen concentration would leave open the possibility that anaerobic or aerobic microorganisms are present in the zone. Aerobic organisms may maintain low oxygen levels by consuming oxygen as it permeates the zone.

The high oxygen concentration reported in Table 3.8 of the RI report also raises concern that the oxygen could contribute to corrosion of the drums causing leaks. Leakage would produce areas of chemical concentrations that may be too high for in-situ microbiological remediation.

High metal concentrations at the site will present problems to microorganisms. Information on metal speciation and concentrations in the various zones was not present. However, non-speciated metal concentrations are high enough for metals to be a problem.

Before any biological treatment can take place, about twenty feet of debris and an estimated 6,000 55-gal drums must be removed in order to treat the underlying soil. Therefore, some disturbance of the contaminated soils would be unavoidable and the economic and hygienic advantages of in-situ bioremediation are lost.

Another important point to consider with respect to bioremediation is that some contaminants present in the waste lagoon might not be successfully treated with bioremediation under any circumstances. For example, chlordane and other chlorinated pesticides may prove to be highly recalcitrant to either in-situ or ex-situ bioremediation within an acceptable time frame.

Finally, tar-like substances reported at the site would tend to foul wells used to force air into the soil during bioventing. This would inhibit further ventilation of the soils and nullify attempts to stimulate biological activity even if potentially active microorganisms were found in the contaminated soil.

Taken together, the above information suggests that in-situ bioremediation is an inappropriate technology for removing contaminants from the waste lagoon area of the Skinner Landfill site.

Soil Vapor Extraction

Soil vapor extraction (SVE) is designed to physically remove volatile compounds from the unsaturated underground zone of a site. It is an in-situ process employing vapor extraction wells; air injection wells may also be required in some situations. Vacuum blowers supply the motive force inducing air flow through the soil matrix. The air strips volatile compounds from the soil and carries them to screened extraction wells. Even though SVE is a developed technology, treatability studies are required to document the applicability and performance of an SVE system because performance capabilities of the technology are site-specific. In general, the process works well in drained soils with low organic carbon content. It has been shown to work in finer, wetter soils, but at slower removal rates. Soil heterogeneities influence air movement. There are no beneficial aspects to using SVE on contaminants such as pesticides, organic corrosives, volatile metals, non-volatile metals and uncertainties exist regarding its effectiveness on halogenated semivolatiles (i.e. test data not available).

At the lagoon portion of the Skinner Landfill, fractured bedrock (shale and limestone) underlay the site. The fractures are clay filled. It would be almost impossible to locate extraction wells in the appropriate area of the strata. Cross sections from the RI/FS show clay and silt from 20' to 40'. There is also shallow groundwater at the south end of the lagoon area. These conditions mitigate against effective SVE because of the low permeability of the soils. In addition, only volatiles in the landfill could be treated by the technology if conditions were more favorable. The semi-volatiles and metals, tar-like substances are not amenable to SVE treatment even under ideal circumstances. For these reasons in-situ is not recommended for treatment of the lagoon area.

EX-SITU TREATMENT TECHNOLOGIES

Plasma Torch (Plasma Arc) Technology

In lieu of using conventional flame-combustion from natural gas or oil to destroy waste, the Plasma Torch concept derives heat from a large, high-energy, electric arc torch. The torch discharges a stream of glowing, ultra-high temperature gases estimated to be at 5,000 to 10,000 degrees Centigrade and called a "Plasma". The plasma is directed at the waste media, and the resulting oxidative or reductive reactions are contained within a strong, insulated vessel much like the primary chamber of an incinerator. In the Retech design (a developer of the plasma arc technology), the intent of the plasma is not only to destroy the toxic organics, it is also to melt or liquify soil, rock, and metals including iron and steel. Batches of these molten solids collect in a rotating device within the primary chamber and are periodically discharged into a mold to cool to a vitreous ingot or casting. Off-gases from the primary chamber gases are processed through an incinerator-like air pollution control system.

If applied to soil contaminated with toxic organic wastes excavated from a Superfund site, a Plasma Torch system is intended to destroy the toxic chemicals while also melting and reducing the original volume of the material to a non-leachable, glass-like solid residue. Research testing to date has demonstrated that this concept indeed has many workable features. However, some unexpected problems have also surfaced, slowing the emergence of this new concept as follows.

Testing by the USEPA in a Butte, Montana pilot plant revealed that the Plasma Torch concept tended to have air pollution problems. The Plasma temperatures that melt the waste also cause volatilization and release of toxic metals. Those high temperatures can also create undesirable amounts of nitrogen oxides or "NO_x" generated from the nitrogen in the air supply to the torch, resulting in visible, yellow/brown stack exit levels of NO_x up around 5,000 to 10,000 ppmv.

Adding a conventionally-fired afterburner chamber similar to that of an incinerator has been found necessary to improve organic destruction and Products of Incomplete Combustion (PIC) minimization. The NO_x issue is still under study, and the potential solutions of using alternate torch gases and/or incorporating a NO_x emission control system are being considered.

Plasma systems are inherently very energy intensive. It has been estimated that a mobile or transportable Plasma Torch system for Superfund site remediation may be too energy intensive to be practical at a number of sites. It may also not be practical to treat waste with high water contents due to the volumes of steam that would be produced.

At this time, USEPA-sponsored testing and analyses conclude that, compared to modern, conventional incineration systems, the Plasma Torch technology is simply not yet sufficiently developed, problem-free, or proven as a field-ready remediation technology for Superfund sites. Solutions to the problems with toxic metals emissions, NO_x, and the large electrical power requirements have not been solved. Applications to Superfund sites like the Skinner site are not feasible at this time.

Stabilization/Solidification (S/S)

Stabilization is the addition of agents that alter the chemical form of the contaminant or chemically bind the contaminant, thereby reducing contaminant toxicity, mobility, or both. Solidification is the addition of agents, such as cement, that trap the contaminant in a solid matrix that is less permeable and less pervious to leaching. Most commercial immobilization processes involve both mechanisms.

S/S techniques can immobilize many heavy metals and certain organics. They have not been shown to be effective on volatile organics and may not be suitable for semi-volatiles. In some cases, it is difficult to evaluate the long-term (> 5 years) performance of S/S and long-term monitoring may be required to insure that the solidified material continues to meet design criteria.

S/S appears inappropriate for treatment of the Skinner Landfill lagoon area for several reasons. First, many of the organic contaminants are volatiles. Since there are no proven S/S techniques for volatiles, these would have to be removed from the waste - this is an extra processing task which is complicated by the low permeability of much of the soil. Second, wastes of high clay content may clump up, interfering with the uniform mixing of S/S agents. A large portion of Skinner soil is clay and achieving success with S/S for clays can be difficult. Third, portions of the lagoon area contains "tarry substances" and drums of unknown composition. Some of this material will likely have a high organic content. Generally, if the waste exceeds 30% organic content or if the toxic organics exceed a few percent, technologies other than S/S are more effective and less costly.

In conclusion, the presence of large concentrations of volatile organics, and the heterogeneous, often clayey soil make S/S an unlikely candidate as a primary treatment technique at this site. S/S appears to be at best suitable for the post treatment of residuals from other treatment technologies which are not restricted by these site characteristics. For instance, if organic matter is removed or destroyed, S/S may be applicable to the treatment of metals in the residual soils.

Chemical Treatment

Chemical treatment techniques alter the chemical composition of a contaminant, either destroying it or reducing its toxicity. These treatment techniques have principally been applied to aqueous and gaseous waste streams. Examples of chemical treatment techniques used in aqueous streams are potassium permanganate or hydrogen peroxide oxidation, sulfur dioxide reduction, and wet air oxidation techniques. There are two principal chemical treatment techniques that have been considered for destruction of organics at Superfund sites: chemical oxidation and chemical dehalogenation. Chemical oxidation uses a chemical reaction to break down a contaminant. It is a non-selective treatment technique which attacks most organic compounds, but at reaction rates which may differ significantly for different types of compounds. Generally, halogenated hydrocarbons and saturated aliphatics are only slowly attacked by oxidizing reagents, while organic compounds containing oxygen (e.g. ketones) are more rapidly attacked.

With the exception of organic cyanides, chemical oxidation does not have a demonstrated effectiveness in soils or sludges. There are a number of other limitations to chemical oxidation techniques which make them inappropriate for the Skinner Landfill. The effectiveness of chemical oxidation varies according to the composition of the contaminants, but they will generally react with most organic matter (including humic matter, etc.) present. Therefore, it is most suited to media with low organic carbon content. If the organic content is high, oxidation is not very cost effective because much of the added chemical oxidants will react with the non-toxic organic matter. This can greatly increase the cleanup cost. In particular, oil and grease, such as is likely to exist in the lagoon area, will reduce the efficiency of this process.

The chemical dehalogenation treatment process which has the most application to hazardous wastes is alkaline metal hydroxide/polyethylene glycol (APEG). This treatment technique has been effective in removing chlorine atoms from aromatic hydrocarbons such as PCBs in soils, sediments and oils, thus reducing the waste toxicity. Because many of the organic contaminants of concern at Skinner Landfill are not chlorinated organics, it is not appropriate for this site.

Thermal Desorption

Thermal desorption is an ex-situ means to physically separate volatile and some semi-volatile contaminants from soil, sediments, sludges, and filter cakes. For waste up to 10% organics or less, thermal desorption can be used alone for site remediation. It may also be applied in conjunction with other technologies or be appropriate to specific operable units.

Thermal desorption is applicable to organic wastes and generally is not used for treating metals and other inorganics. Chemical contaminants for which bench-scale through full-scale treatment data exist include primarily volatile organic compounds (VOCs), semivolatiles, and even higher boiling point compounds, such as polychlorinated biphenyls (PCBs). The technology is not effective in separating inorganics from the contaminated medium. Volatile metals, however, may be removed by higher temperature thermal desorption systems.

Depending on the specific thermal desorption vendor selected, the technology heats contaminated media between 200-1000°F, driving off water and volatile contaminants. Offgases may be burned in an afterburner, condensed to reduce the volume to be disposed, or captured by carbon adsorption beds.

Based on the current available data, thermal desorption is not a viable alternative for this site for the following reasons:

- The physical characteristics of some of the waste (sticky tars, some liquids) are not amendable to thermal desorption treatment. Thermal desorption works best on flowable solids such as contaminated soils.

- The boiling points of many of the contaminants, such as 2,3,7,8-TCDD, PCBs, pyrene, chrysene, and phenanthrene, are higher than the maximum soil treatment temperature of some types of commercially available thermal desorption systems, such as hot oil heated thermal screws and rotary dryers constructed of carbon steel. These compounds would not be removed at high efficiencies (>95%) at temperatures below 700°F. (See Figure 1)

- The total concentrations of organic materials in portions of the waste lagoon are reported to exceed 3 percent. Average concentrations of organics in the feed should generally be less than 3 percent for most rotary dryers in order to avoid exceeding the lower explosive limit in the dryer offgas.

- Thermal desorption systems do not process debris. It is likely that there is a great deal of debris in the waste lagoon that would have to be decontaminated by alternative treatment methods or treated at offsite facilities.

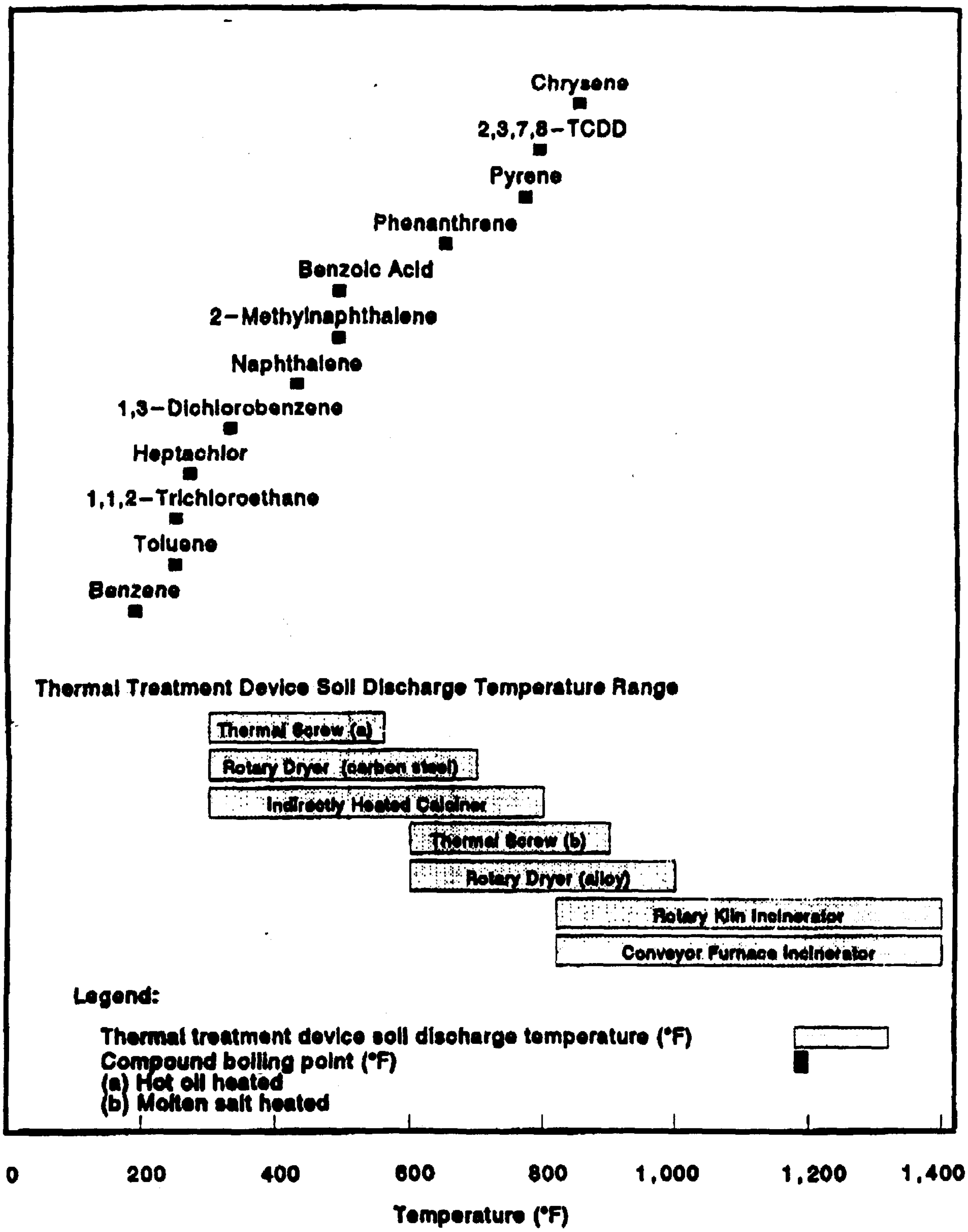

Figure 1. Boiling Point Versus Thermal Treatment Device Soil Discharge Temperature

- o There are reported to be up to 7,700 drums buried in the waste lagoon. Types of wastes that were known to be deposited in the lagoon include ink sludges, pesticide wastes, and paint pigments. Thermal desorption systems are not applicable for processing highly concentrated chemical wastes such as those that are likely to be contained in the drums.

<u>Soil Washing</u>

Soil washing is a water-based process for mechanically scrubbing soils ex-situ to remove undesirable contaminants. The process removes contaminants from soils in one of two ways: by dissolving or suspending them in the wash solution (which is later treated by conventional wastewater treatment methods) or by concentrating them into a smaller volume of soil through simple particle size separation techniques (similar to those used in sand and gravel operations). Soil washing systems incorporating both removal techniques offer the greatest promise for application to soils contaminated with a wide variety of heavy metal and organic contaminants.

Soils containing a large amount of clay and silt typically do not respond well to soil washing, especially if it is applied as a stand alone technology.

While the contaminants in the lagoon are amendable to soil washing, the use of soil washing at the Skinner Landfill would pose a number of problems. The large volume of debris (bricks, rubber, glass, wood, scrap metals, drums, etc.) would have to be excavated before soil washing could be attempted. The resulting volatiles would require another form of treatment. In addition, the soils containing black liquids and tar-like materials would have to be removed because these materials would foul the mechanical systems of the soil washer and would not be easily dissolved or remediated in a soil washing process.

If the debris were removed for another form of treatment, there would be at least two remaining problems that indicate soil washing is not suitable for this site. The first is the number of contaminants present that would require a variety of treatment trains and wash fluids. The organics would require a surfactant in a basic solution while an acidic solution would be necessary to remove the inorganics. The second problem is the significant amount of clay and silt present. Soil washing is not cost effective when dealing with these particle sizes. The volume reduction obtained would not be substantial.

<u>Solvent Extraction</u>

Solvent extraction is a technology used to separate hazardous contaminants from soils, sludges and sediments, thereby reducing the volume of contaminated material to be treated. Solvent extraction does not destroy contaminants, but is generally used in a series of unit operations to reduce the volume of wastes that require treatment and consequently to reduce the overall cost of treatment. Solvent extraction has been shown to be effective in treating sediments, sludges and soils containing primarily organic contaminants such as polychlorinated biphenyls, volatile organic compounds, halogenated solvents and petroleum wastes. The technology is generally not used for extracting inorganics. Any organically-bound metal can co-extract with the target organic pollutants and become an additional constituent to be treated in the concentrated organic waste stream.

With regard to the lagoon area of the Skinner Landfill, solvent extraction would not be effective as a primary remediation technology. The major difficulty concerns the physical make-up of the lagoon, i.e., large amounts of various kinds of debris and buried drums. Debris of this nature is inappropriate feed material for commercial solvent extraction systems.

The source segregation required to prepare a portion of the lagoon waste for treatment via solvent extraction would be a significant added expense, particularly because volatile organic emissions would have to be controlled. Given the large number of barrels in the lagoon, a large portion of the lagoon waste might not be treatable by solvent extraction. Solvent extraction has not, to our knowledge, been applied to a site with the debris and barrels found at the Skinner Landfill. Therefore, there is no proven record on which to base the feasibility of the technology to such a complex matrix.

There are two other drawbacks with applying solvent extraction to the Skinner Landfill. Any metal contaminants in the waste which are not organically bound would not be removed and have to be treated further. In addition, the cleanup goals for a number of contaminants are in the low parts per million level. Without testing on actual waste samples, we cannot be certain that present solvent extraction technologies can reach these levels.

Ex-Situ Bioremediation

Ex-situ bioremediation of soils involves aerobic biodegradation of organic contaminants in excavated soil. This can be accomplished by composting or slurry reactor. Biodegradation occurs when suitable conditions (oxygen, nutrients, water, temperature) are arranged for microorganisms to utilize organic contaminants as a food source.

Two ex-situ bioremediation technologies were considered: composting and a slurry reactor system. Land treatment (i.e. "land farming") was not considered because control of volatile organic emissions would be more difficult than with the other two technologies.

In soil composting, the contaminated soil is mixed with nutrients, bulking agents and water. Microorganisms already present in the soil may degrade the contaminants under appropriate conditions, or an inoculum of microorganisms may be added via sludge or manure. The soils are excavated and placed in piles or rows that can be aerated or mixed at appropriate intervals. Additional moisture and nutrients can be added as needed. Remediation may require 6 to 12 months per batch depending on the types and amounts of contaminants.

A field slurry reactor system consists of an aqueous slurry created by combining soil or sludge with water. This mixture is aerated and agitated in either a closed reactor or a lined lagoon. Slurry biodegradation is useful for treating high concentrations of soluble organic contaminants, and reducing the volume of contaminated material. This technology is still developmental, but appears to offer promise as a cost-effective hazardous waste treatment method.

There are a number of problems associated with applying either of these technologies at the Skinner Landfill.

1. Since bioremediation involves relatively slow processes, special measures are required to limit loss of volatile organics into the atmosphere as air pollution. The very high concentrations of volatile compounds discovered in the Skinner Landfill waste lagoon will create significant containment problems if ex-situ bioremediation is implemented. Fugitive emissions of volatile organic compounds from soil to ambient air will be difficult to control during excavation of contaminated soil from the waste lagoon.

2. Furthermore, in order to treat waste lagoon soils by ex-situ bioremediation, debris, waste drums, and other materials that may interfere with the biological processes must be separated from the treatable soil. The time required for this procedure will provide additional time for volatile organic compounds to escape from the soil, thereby increasing the potential for fugitive emissions into the atmosphere.

3. Ex-situ bioremediation at the Skinner Landfill waste lagoon may provide a suitable technology for partial remediation. However, complete remediation is probably not possible using this technology alone. Some contaminants present at the site might not be bioremediable under any circumstances. For example, chlordane and other chlorinated pesticides may prove to be highly recalcitrant to any form of bioremediation within an acceptable time frame.

4. Finally, bioremediation can remove 90% to 99% of some organic compounds. If lower levels of these compounds are required, alternative technologies must be applied in addition to, or in place of, bioremediation.

Summary

In conclusion, none of the treatment technologies that we considered as potential alternatives to incineration are currently practical options for remediation of the mix of contaminants in the lagoon area of the Skinner Landfill. Matrix conditions (e.g. clay and silt, debris, and buried barrels) and highly variable contaminant concentrations would create problems for the in-situ technologies such as soil vapor extraction and bioremediation.

The alternative ex-situ treatment technologies that we considered are impractical for one or more reasons. The plasma arc has not been demonstrated adequately to warrant full-scale application at Superfund sites at this time (and has some of the other shortcomings noted below relative to the Skinner Landfill). Available chemical treatment processes are either specific to halogenated organics or have not been proven cost effective for soil remediation, particularly with such a variety of contaminants. Experience with solvent extraction and bioremediation indicates that these technologies may not be able to meet the cleanup goals at the site, particularly in the case where these goals are 1 or 2 parts per million.

In addition, all the ex-situ technologies that we considered would require additional materials handling over and above that which would be required for incineration. This is because these alternative treatment technologies cannot affectively treat the debris, viscous masses (e.g. tars) and barrel contents found in the lagoon area even after such material has been shredded. Therefore, part of the lagoon wastes would have to be separated out and disposed of by conventional processes (e.g. incineration, landfilling). While it is difficult to estimate the volume of material that would still have to be disposed of through conventional means, it appears to be significant.

Besides not being able to treat the total volume of lagoon waste with any of these alternatives, additional volatile organic emissions (VOC) controls would be required for the source separation processes. This would add to the remediation costs and to the potential for VOC releases.

Finally, the wide variety of organic contaminants and the large variability in their concentrations at the Skinner Landfill site adds additional uncertainties about whether your cleanup objectives can be reached by these alternative treatment technologies. High temperature incineration can more readily handle this type of complex waste stream because combustion is such a severe process. The other technologies rely on weaker forces to drive contaminant destruction, separation or immobilization for waste treatment. (Plasma torch and ISV are exceptions since they also use high temperatures.) Therefore, none of these alternative technologies have the certainty that incineration has for decreasing contamination to the required levels.

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